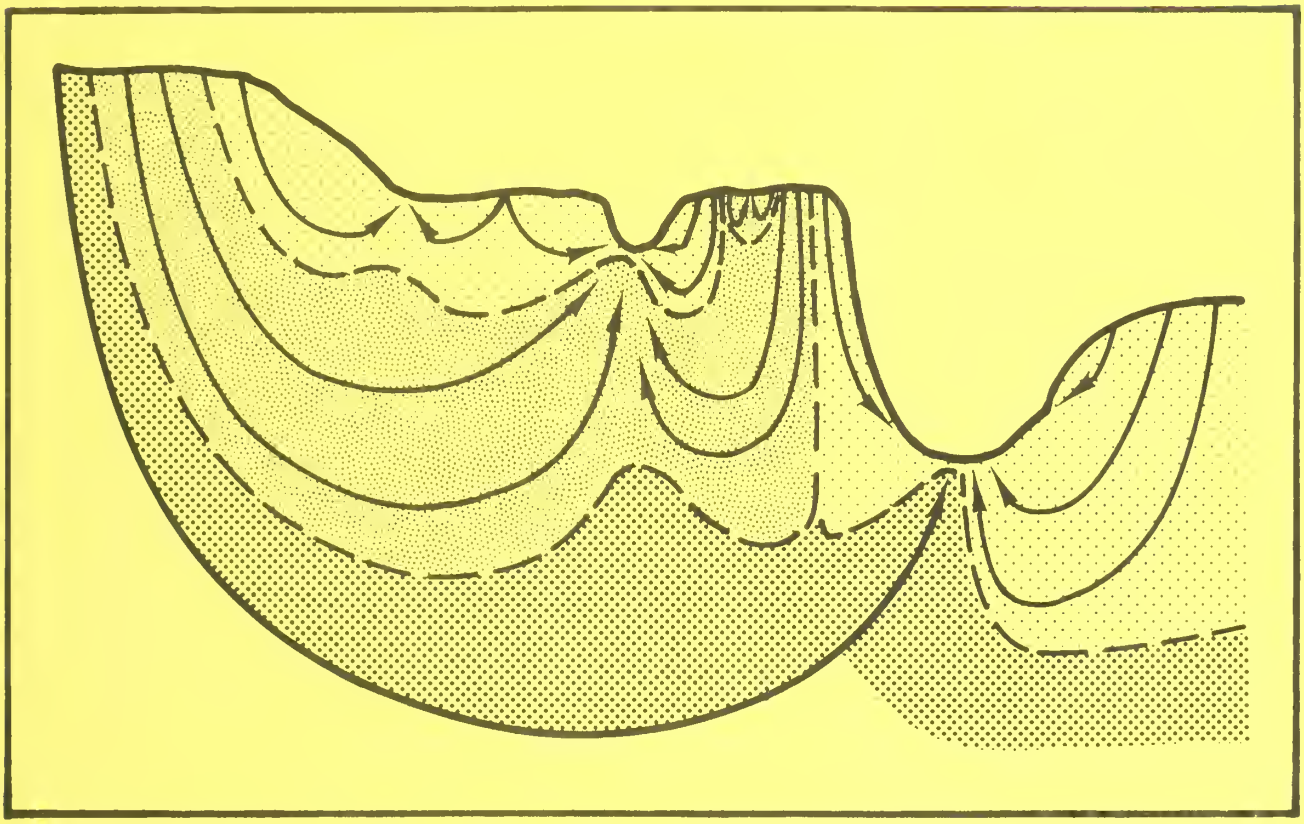
Geol Survey

Hydrogeologic aspects of coal mining in Illinois: an overview

Keros Cartwright and Cathy S. Hunt



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Hydrogeologic aspects of coal mining in Illinois: an overview

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ABSTRACT

Water has generally not been a significant problem in Illinois mining, although most Illinois coal mines (both surface and underground) lie partly or completely below the water table. Water-related problems in and around mines are likely to increase as it becomes economically feasible to open or expand surface mines in areas with thicker and more permeable overburden and to place underground mines at greater depths. Detailed study of the hydrogeology of mining areas before, during, and after mining can help prevent problems that may occur. Such analysis should include: (1) a study of the topography of the land surface and patterns of surface flow (especially for surface mines); (2) the identification and characterization of aquifers in the glacial drift and in the bedrock; (3) an estimate of the effects of surface or ground water flow on mining; and (4) an evaluation of the effects of mining on surface streams and on aquifers. With this information mines can be designed to be productive, efficient, and environmentally sound.

CONTENTS

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INTRODUCTION

Although most coal mines in Illinois (both surface and underground) lie partly or completely below the water table, water has generally not been a significant problem in Illinois mining. In a 1975 survey of pumping records of 15 operating underground mines made by the Illinois State Geological Survey, 11 mines reported pumping from near zero to less than 3,530 cu ft (100 cu m) of water per day; four mines reported pumping between 10,590 and 176,600 cubic feet (300 and 5,000 cubic meters) per day. However, as it becomes economically feasible to open surface mines in areas with thicker and more permeable overburden and to place underground mines at greater depths, problems with water influx are likely to increase.

Because water has not been a problem in Illinois mining, few studies have been done on the hydrogeology of mining areas—and most of these studies have been attempts to alleviate specific water problems that had developed in individual mines. No extensive, systematic hydrogeology studies of an area before, during, and after mining have been conducted; yet data resulting from such study would make it possible to predict the effects of mining on surface flow and/or ground water reservoirs, to anticipate water or water-related problems during mining, and to plan appropriate reclamation procedures for each mine.

Surface mines in Illinois are usually located in areas with thin glacial drift overlying bedrock; however, surface mines are now being proposed in areas of thick drift. In designing such mines, it is important to know whether a shallow aquifer may drain into the mine workings and to anticipate the potential effects of such drainage on mining procedure and on nearby water wells; it is also important to know if the mining operation planned is likely to change the pattern and water quality of stream flow in the area.

Underground mines in Illinois are located well below the water table; however, the geologic materials are generally tight. The most significant problem in underground mining is the flow of water into the mine workings. If an aquifer or even a unit slightly more permeable than the other rock units occurs near the mine the approximate volume and duration of flow into the mine can be estimated. It is also possible during the planning stage to: (1) identify areas where flow may be concentrated (along faults and joints) and to anticipate water and water-related problems; (2) to determine whether an aquifer will be drained by mining and, if so, what wells will be affected; and (3) to set up procedures designed to minimize post-mining subsidence problems.

GROUND-WATER SYSTEMS

All earth materials have some capacity for transmitting fluids via pore spaces (in other words, they are permeable). The permeability of a material depends on the size and shape of the pore spaces and on the size, shape and extent of the interconnections of the pore spaces. Ground water moves through pore spaces as a result of potential, or energy gradients. When

there is enough rainfall, some of the precipitation moves downward through the soil to a zone of saturated sediments and rock. The water then flows through the pore spaces in the rock to some point of ground water discharge. This is a flow system in which the driving force is gravity.

The route water takes to a discharge point is known as the flow path; a flow system is a group of flow paths with the same recharge and discharge areas. Water in a local flow system enters the ground and flows to the nearest area of discharge, usually a stream or a pond. The flow paths in an adjacent intermediate flow system are longer than the paths in the local flow system. Flow paths in an adjacent regional flow system are still longer and the flow is toward a major river or lake (fig. 1).

Some of the precipitation reenters the atmosphere through evaporation from the soil and through transpiration from vegetation. The rest flows through the unsaturated soil until it reaches saturated soil or rock. This unsaturated soil zone is called the zone of aeration and is separated from the zone of saturation by a boundary known as the water table.

The water table is not a fixed boundary; in most regions it fluctuates upward or downward. For example, during periods of high rainfall water enters the zone of saturation and the water table rises; during a drought the water table moves downward enlarging the zone of aeration. A common misconception is that the water table defines the surface of a zone from which one can pump water. Actually, the water table occurs in earth materials that may, or may not, yield water to wells depending on their hydraulic conductivity (their ability to transmit water). Hydraulic conductivity determines the amount of fluid that can be withdrawn from that material and is a property of an earth material and also of the fluid filling the pore spaces of that

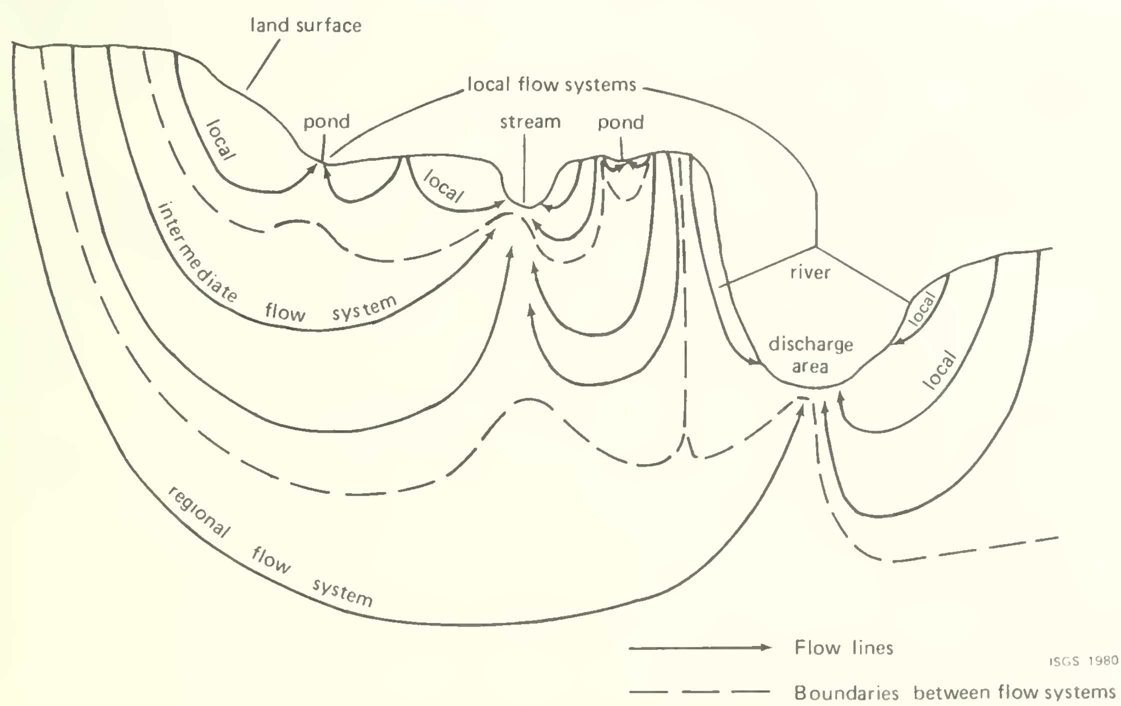

Figure 1. Generalized ground-water patterns illustrating the effect of topography on ground-water flow.

material. In common usage, hydraulic conductivity and permeability are used interchangeably. In saturated materials, hydraulic conductivity is constant; in unsaturated materials the hydraulic conductivity varies with the moisture content. Saturated clay tills do not readily transmit water (they have very low hydraulic conductivities) and thus yield little water to pumping; saturated sand and gravel have very high hydraulic conductivities and can yield large quantities of water when pumped. Even a well finished below the water table can be "dry" if the hydraulic conductivity is low at that depth.

Figure 2 shows water filtering from the surface through the zone of aeration to the zone of saturation. This process is controlled by the field capacity of soil (the ability of the soil to hold water against the force of gravity).

When the soil moisture content is below field capacity, the rainwater entering the soil stays in the unsaturated zone; when the soil reaches field capacity (and only at that time) water passes readily down through to the water table. Thus, water does not get to the water table every time it rains, but only when certain soil conditions exist. Although we cannot determine precisely the field capacity of a particular soil, we do know the general range for many rocks and solids. Many of our glacial tills in Illinois may have a field capacity as high as 90 percent of the total porosity--that is, the pores in the till must be 90 percent filled with water before any significant quantity of water can flow through by gravity; the field capacity of sand is about 10 to 30 percent; the field capacity of mine spoil is estimated to be around 20 to 40 percent.

Water passing through the unsaturated zone generally percolates downward; some of it passes to the water table and into the ground water system. Lateral water movement in the unsaturated soil zone occurs in response to impermeable soil layers and varying soil moisture conditions. Because moisture movement in the unsaturated soil zone is complex, it is difficult to make generalizations about flow patterns in that zone.

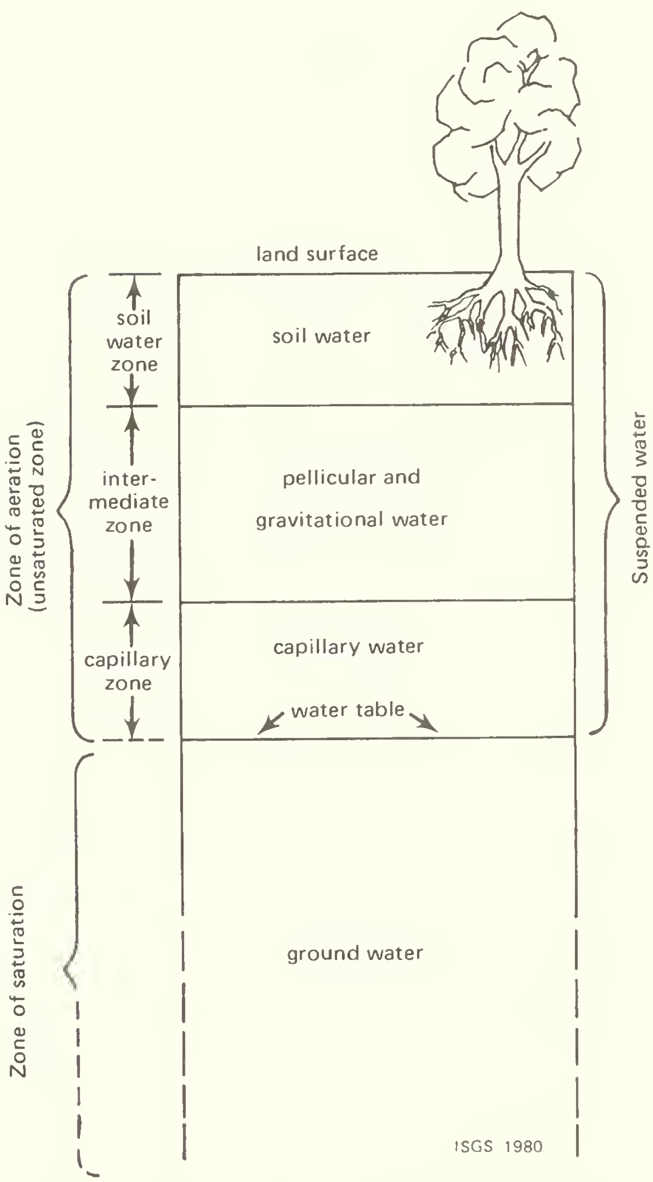

Figure 2. Divisions of subsurface water. The zone of aeration consists of interstices occupied partly by water, partly by air. The soil water zone activity supplies water to plants. Gravitational water is excess soil water which drains through the soil because of gravity. Capillary water exists as continuous films around the soil particles. The zone of saturation is that part of the subsurface in which the interstices are filled entirely by water (from Todd, 1959).

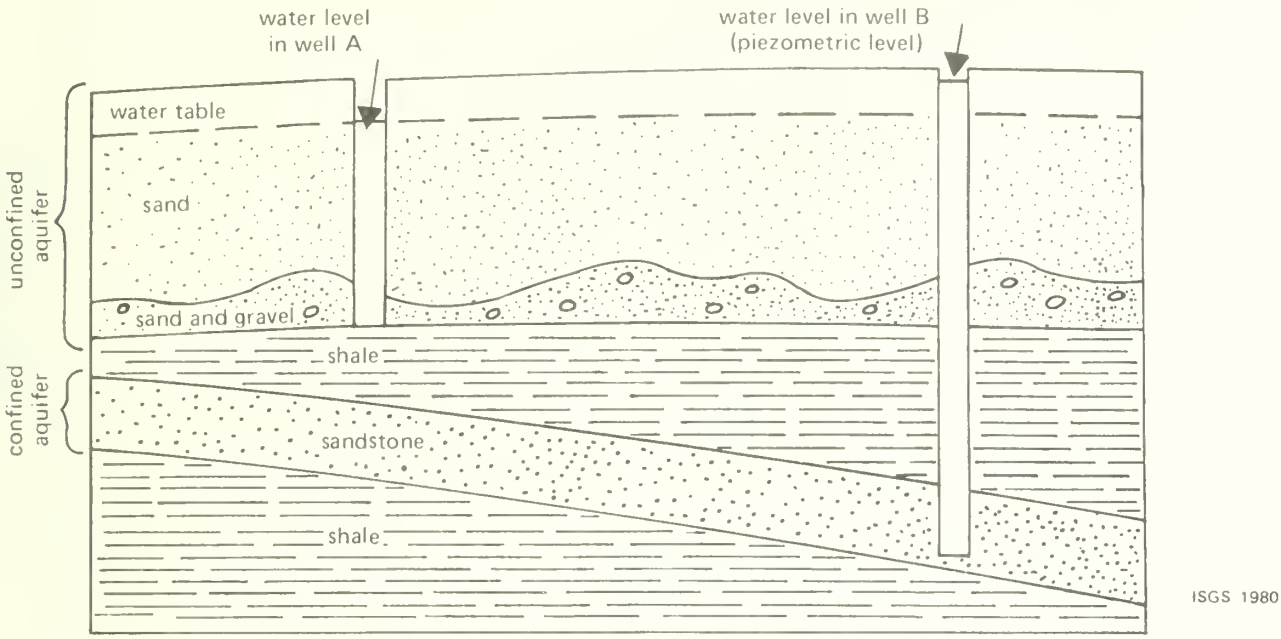

Figure 3. A typical occurrence of aquifers in Illinois, illustrating the difference between an unconfined (water table) aquifer and a confined aquifer.

Flow of ground water in the saturated zone is better understood; it results from differences in the energy (or potential) of the water in a ground water system. (The energy of water at any point depends on its position within a gravitational field). Within the ground water system water flows from areas of high energy to areas of low energy; the rate of flow is determined by both the magnitude of the difference in energy and by the hydraulic conductivity of the rock. The greater the energy and the higher the hydraulic conductivity of the rock, the greater the rate of flow will be.

Soil and rock formations that have high hydraulic conductivities and yield water to pumped wells are called aquifers. Soil and rock formations that have low hydraulic conductivities do not yield water to pumped wells are called aquicludes. A saturated aquifer is an "unconfined" or "water-table aquifer" when it is hydraulically connected to the water table by rocks of high hydraulic conductivity. The potential of the water at any point in an unconfined aquifer is about equal to the potential of the water at the overlying water table. (Variations occur because of energy loss due to ground water movement.) A saturated aquifer is "confined" when it is bounded by aquicludes; the potential of water in a confined aquifer can differ from the potential of water at the overlying water table. The "piezometric level" of water in a confined aquifer is the level to which the water will rise in a well finished in the aquifer; the "piezometric surface" is the water levels in a number of such wells.

In figure 3 the water level in well A (finished in an unconfined aquifer) is at the same elevation as the water table. This indicates equilibrium

between the water in the unconfined sand and gravel aquifer and the water at the table—in other words, the potential of the water in the aquifer is equal to the potential of the water at the water table. The water level in well B (finished in a confined aquifer) is above the level of the water table indicating the piezometric level of the water in the confined sandstone aquifer at that point. In this case the potential of the water in the sandstone aquifer is greater than the potential of the water at the water table; however, the water level need only be above the top of the aquifer to be "artesian" or confined. Flowing wells occur where the piezometric level is above land surface.

The relationship between the ground water system and stream flow is an important aspect of the hydrogeology of an area. Ground water moves through the ground to a point of discharge (generally a spring, stream, river, swamp, pond, or lake), and this discharge provides the "base flow" of these waterways. According to Walton (1965), base flow accounts for 50 percent of all the water flowing in Illinois streams and rivers. In addition to the base flow, surface runoff from rainfall, snow melt, and water moving through the unsaturated soil zone all provide water to waterways.

The ratio of base flow to the total flow of a stream depends on the physical properties of the rock and soil in the water shed; highly permeable rock and soil allow more precipitation to enter the gound water system than do slowly permeable materials. As the ground water is drained from the surrounding earth materials and the water table drops, the magnitude of base flow (and, generally, total flow as well) in a stream decreases. The size of the ground-water basin (the area between the recharge and discharge) also controls the magnitude of ground-water discharge to a stream and thus the magnitude of base flow.

The Illinois Basin Coal Field is a flat region; its surface has been glaciated except for parts of southern Illinois, southern Indiana, and Kentucky. The bedrock dips gently toward the center of the Illinois Basin. The dips on the beds are generally less than 1 to 2 degrees; thus, the coal seams are, for practical purposes, flat. The Pennsylvanian System consists of an alternating sequence of sandstones, shales, limestones, and coals. The Pennsylvanian rocks containing the coal seams are the uppermost rock unit of the region and are overlain only by a variable sequence of glacial and other unconsolidated deposits.

Water entering Illinois surface mines is generally fresh; water found in the underground mines in Illinois varies considerably in quality, but is generally brackish to highly saline. The relationship of depth to water quality in northern Illinois differs significantly from the depth-to-water quality relationship in the Illinois Basin (fig. 4). Water quality generally deteriorates very rapidly with depth in the Illinois Basin, and fresh water is usually found at depths of 100 meters or less. This relationship is only a generalized one, however; it is not an indicator of water quality at each specific site. The analysis of total dissolved minerals plotted against depth for the 32 water samples obtained from underground mines in Illinois (fig. 5) illustrates the relationship of deteriorating water quality to depth, with several notable exceptions. Water fresher than might be expected generally occurs near more permeable, fresh, or brackish water aquifers. The more saline waters generally occur where upward migration of saline waters from deeper formations has been postulated (Cartwright, 1970). Thus, the position of the

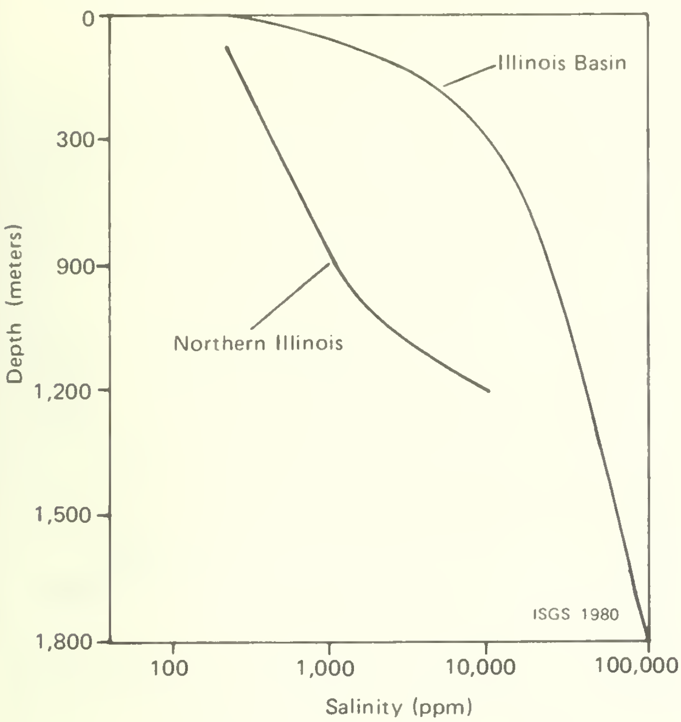

Figure 4. Generalized depth salinity relationships in northern Illinois and the Illinois Basin.

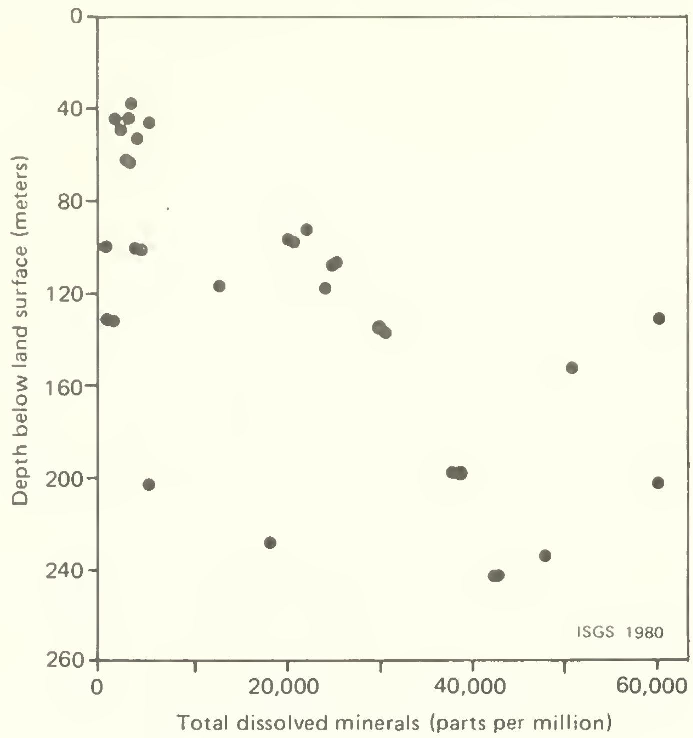

Figure 5. Salinity vs depth of 32 samples from underground mines. Data points from Gluskoter (1965) and Cartwright and Hunt (1978).

mine within the total ground-water flow system partially determines the quality of water from the mine.

SURFACE MINES

Since parts of the large surface mines in Illinois usually lie below the water table, the configuration of the local water table is altered during mining; the mine pit becomes the new local discharge point and ground water flows toward the mine. While the mine is operating, however, the water entering the mine is generally pumped out of the mine into streams or ponds, creating a water table which slopes toward the mine and maintains the flow of ground water to the mine. (The conical configuration of the water table around the mine is known as a "cone of depression".) When abandoned, the mine will fill with water and an equilibrium water level will again be attained.

The effect of dewatering on nearby wells depends on the hydrogeologic properties of the materials being drained. In a typical situation in southern Illinois (fig. 6) a farmer may have a large-diameter bored well in clay till with thin lenses of sand, sandy clay, and sand and gravel from which he obtains a small ground water supply. Shale bedrock underlies the drift deposits. The line of the original water table in the till is usually difficult to determine and has been arbitrarily defined in the diagram. Till has a low hydraulic conductivity (ranging from 10^{-5} cm/sec to 10^{-8} cm/sec) and in figure 6 the hydraulic conductivity of the shale is assumed to be lower than the till. When the highwall is cut and ground water begins to flow toward the mine, seeps will appear along the till-bedrock contact on the high wall and the water table is lowered. However, because of the low hydraulic conductivities of the till and shale, the resulting cone of depression is of

limited extent, possibly only about 3 meters (10 ft) up to 60 meters (200 ft). In this case the farmer's well will not be affected.

In a less common situation in Illinois (but certainly a possible one, given the variability of the drift deposits) a farmer may have a small-diameter, drilled well finished in a shallow sand and gravel aquifer in the drift (fig. 7). Above and below the aquifer are aquicludes. In southern Illinois the upper aquiclude is most likely to be till, the lower aquiclude shale. When the highwall of the mine is cut, the ground water in the aquifer will flow toward the mine and the ground water present in the upper aquiclude will drain downward toward the aquifer. The resulting piezometric level may still be above the aquifer at the well; however, if that well is pumped, the drawdown resulting from pumping will bring the piezometric surface below the top of the aquifer. This will cause well problems, including a decreasing yield of the well. Further pumping will drain the top of the aquifer. The well pump would then have to be lowered into the aquifer next to the well screen, which might cause the well screen to clog or result in the pumping of sediment. For practical purposes, this well would then be nearly useless.

In this case, extent of the area affected by the mine would depend on the thickness and hydraulic conductivity of the aquifer and the hydrogeologic properties of the upper aquiclude. However, the affected area would be much greater than in figure 6 (probably anywhere from several hundred meters to as much as a kilometer or two). The situation illustrated in figure 7 might also occur when a sandstone aquifer lies between two shales or between a till and a shale. Near a surface mine the difficulties with a well finished in sandstone above the coal would be the same as with one finished in a drift aquifer.

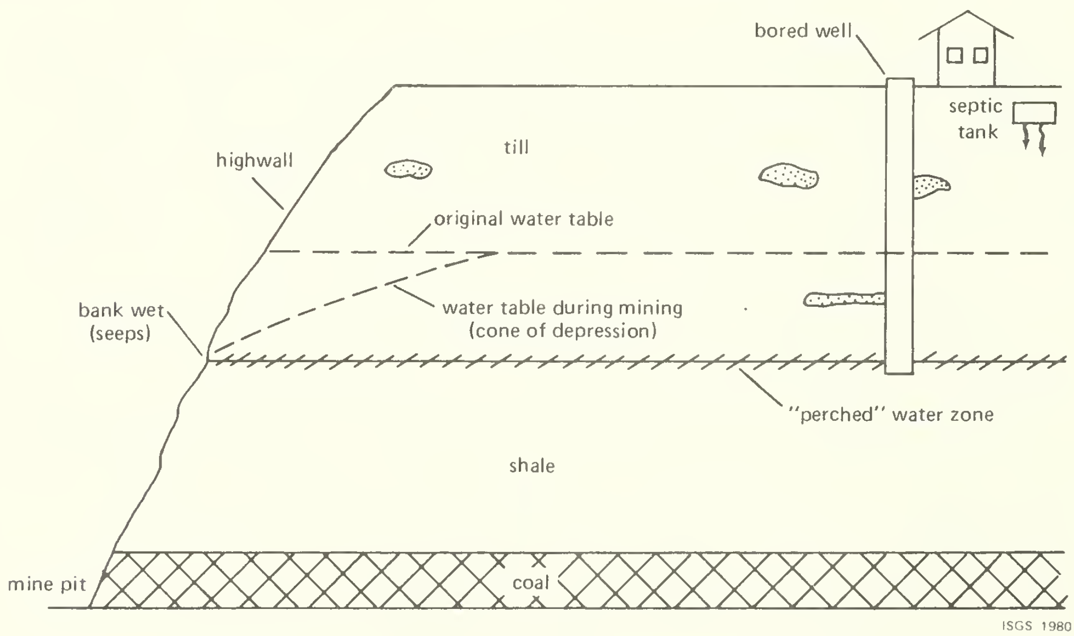

Figure 6. A well finished in low conductive geologic material near a mine pit (a limited area is affected by mining).

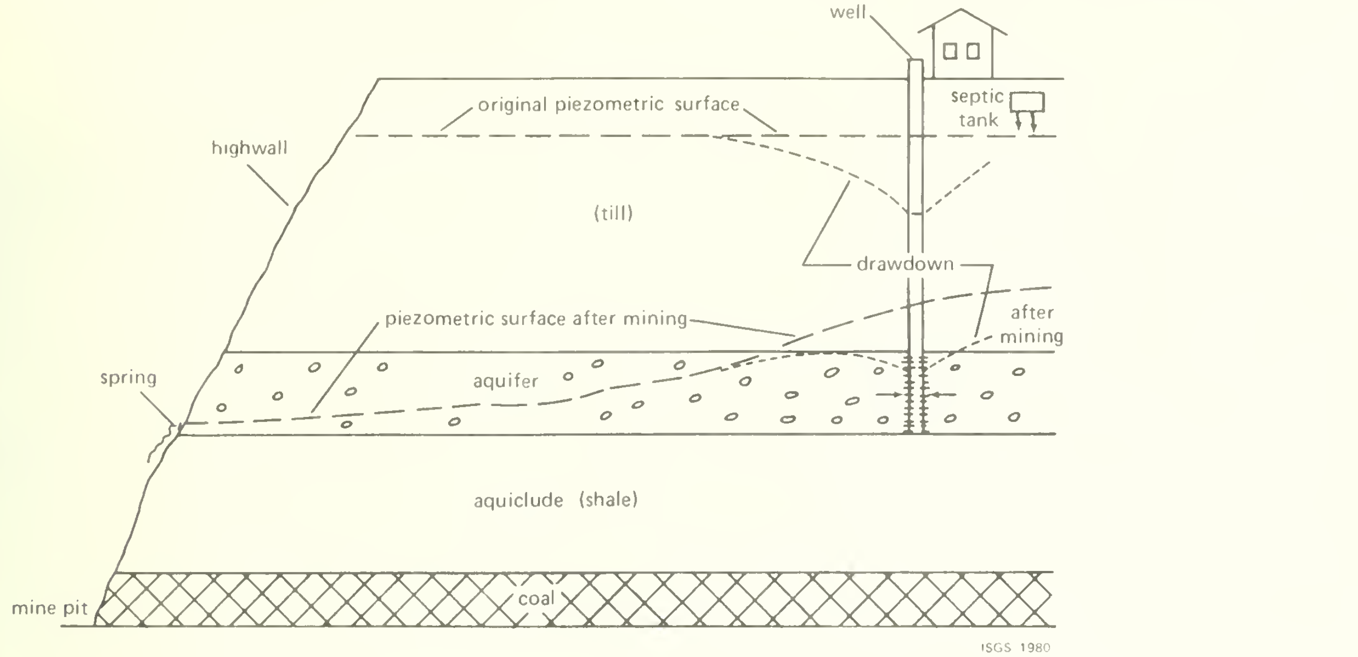

Figure 7. Effects of mining on a well finished in a permeable aquifer near a mine pit.

Until the past few years drainage of wells by nearby surface mining operations has not been a serious problem since most of the Illinois surface mines have been located in areas similar to that illustrated in figure 6. However, some Illinois areas have recently been experiencing droughts, and in drought years there is less recharge to the soil from precipitation and the water table is likely to become somewhat lower. If the water table is lowered, the distance from the mine at which wells may be affected increases and a previously unaffected well may go dry. The question of responsibility for a problem such as this becomes complicated, since both mining and drought are involved. Because Illinois coal can now be economically stripped at greater depths than before, the situation illustrated in figure 7 is likely to occur more often than before. Highwalls of 30-40 meters (100 to 150 ft) are being planned tor certain mines, and the greater the thickness of the overburden, the greater the chance of encountering an aquifer of significant thickness and lateral extent. A survey of wells within a radius of several miles from the mine could determine whether water supplies in the area are obtained from a single aquifer, and examination of the cores from the exploratory drilling program could determine the hydrogeologic properties of the overburden and thus aid in the prediction of possible hydrogeologic problems.

The reclamation of surface mines can also create hydrogeologic problems. When the mining is finished and the mine is reclaimed (using the mine spoil) a new hydrogeologic regime is created. The mine spoil generally consists primarily of blocks of tills and shales with smaller amounts of sandstones and limestones, and drift sand and gravel. A man-made aquifer may be created because the hydraulic conductivity of the spoil material may be high in comparison with that of the original undisturbed material (it is easier for water to filter through the cracks and larger openings in the mine spoil than through the pores of the soil). The water table may rise because of the

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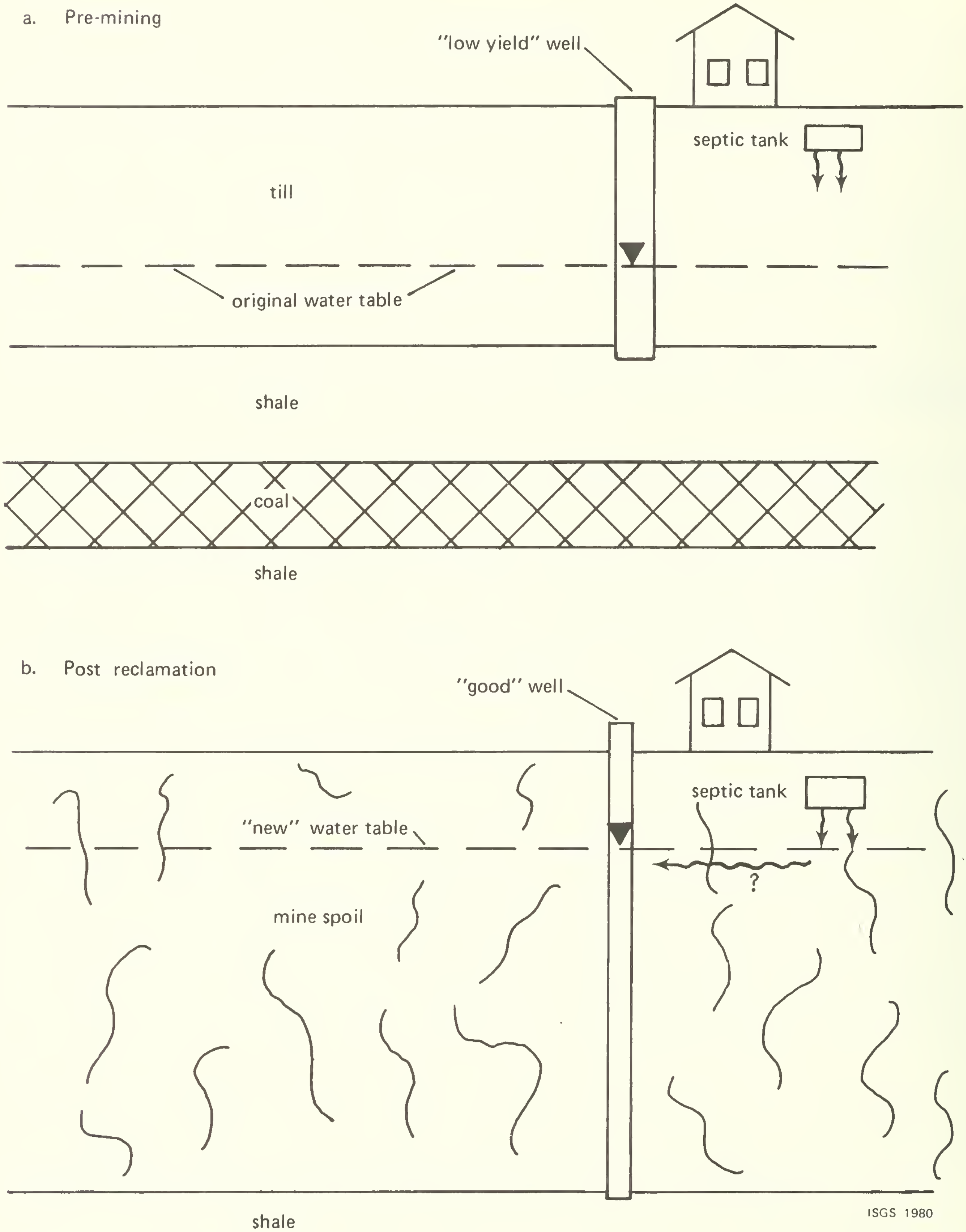


Figure 8. A typical hydrogeologic situation in southern Illinois (a) before mining and (b) after reclamation.

increased infiltration of precipitation. Typical situations prior to surface minings and after reclamation are illustrated in figures 8a and 8b. When water flows through the pores of a soil, a natural filtering of sediment (possibly contaminants) occurs; but when water flows through cracks and crevices, little filtering occurs. In 8b a properly-constructed, water-yielding well is finished in the mine spoil and a septic system may be contaminating the well.

A situation similar to this may have accounted for water quality problems encountered in a subdivision built on a reclaimed mine in Fulton County, Illinois (Lindorff, D. L., personal communication). Mining had removed about 15 meters (50 ft) of glacial drift as well as bedrock down to the coal. The mine was reclaimed 20 to 30 years ago and the mine spoil was used as fill. New wells in this area indicate that there are 6 to 30 meters (20 to 90 ft) of spoil fill (probably consisting of drift material and broken rock) over solid bedrock. The rate of movement through this material probably is more rapid than that through the glacial drift and rock present prior to mining. Water wells completed in the spoil material may be more easily contaminated by rapid movement of relatively unaltered septic effluent from the septic systems, also placed in the spoil.

A third hydrogeologic consideration is the effect of surface mining on stream flow. Figures 9 and 10 are stream hydrographs illustrating the effects of surface mining runoff (DeWiest, 1966, and Corbett and Agnew, 1968). Figure 9 shows diagramatically the effect on the stream runoff when the mine pits are left to fill with water after mining has ceased. In this diagram the soil is assumed to be fairly impermeable in both the mining and post mining conditions. The rate of runoff generated by a storm prior to mining is represented by a peak in the hydrograph which falls off rapidly. Most of the storm precipitation goes into surface runoff and there is little ground-water recharge. The process of stripping creates reservior-like surface water storage, in which some of the storm precipitation is stored. The storm runoff peak is lowered and broadened as surface water is stored in the mine-pit ponds. For people living downstream this may be an environmental gain because flooding may be reduced.

Figure 10 illustrates the effect on stream runoff when a surface mine is reclaimed. The stream hydrograph for the pre-mining condition is the same as that used in figure 9. If the spoil used for reclamation is highly permeable, the amount of infiltration at the site will be increased; this allows for greater ground-water storage, and the base flow of the stream resulting from ground-water runoff will be much greater. This extensively broadens the storm runoff peak. In this situation, a man-made aquifer has been created to store and slowly release the storm water. Flooding downstream due to storm runoff would diminish.

The most recent work on the hydrogeologic factors of surface mining has been in the western states. In these states there are extensive Cretaceous and Tertiary coal beds. Because many of these coals are low in sulfur (in contrast to most Illinois coals) they are currently in demand. Many western coal beds are very thick, and some are aquifers. In some areas, the coal aquifers may be the only source of water. For this reason, there has been concern over what effect the development of surface coal mines will have on local ground water supplies. Van Voast and Hedges (1975) studied the potential

effects of two proposed extensions of the Decker Mine (in southeastern Montana) on local wells and a nearby reservoir. They determined that only a few wells would be made unusable by mining, found that the effluent discharged into the Tongue River Reservoir would not cause detectable deterioration of the water quality in the reservoir and predicted that when mining was completed, the water levels in the affected wells would rise toward pre-mining levels and pre-mining ground water flow patterns would gradually resume.

UNDERGROUND MINES

All currently operating underground coal mines in Illinois are situated in Pennsylvanian bedrock, well below the water table. Many of the drier mines

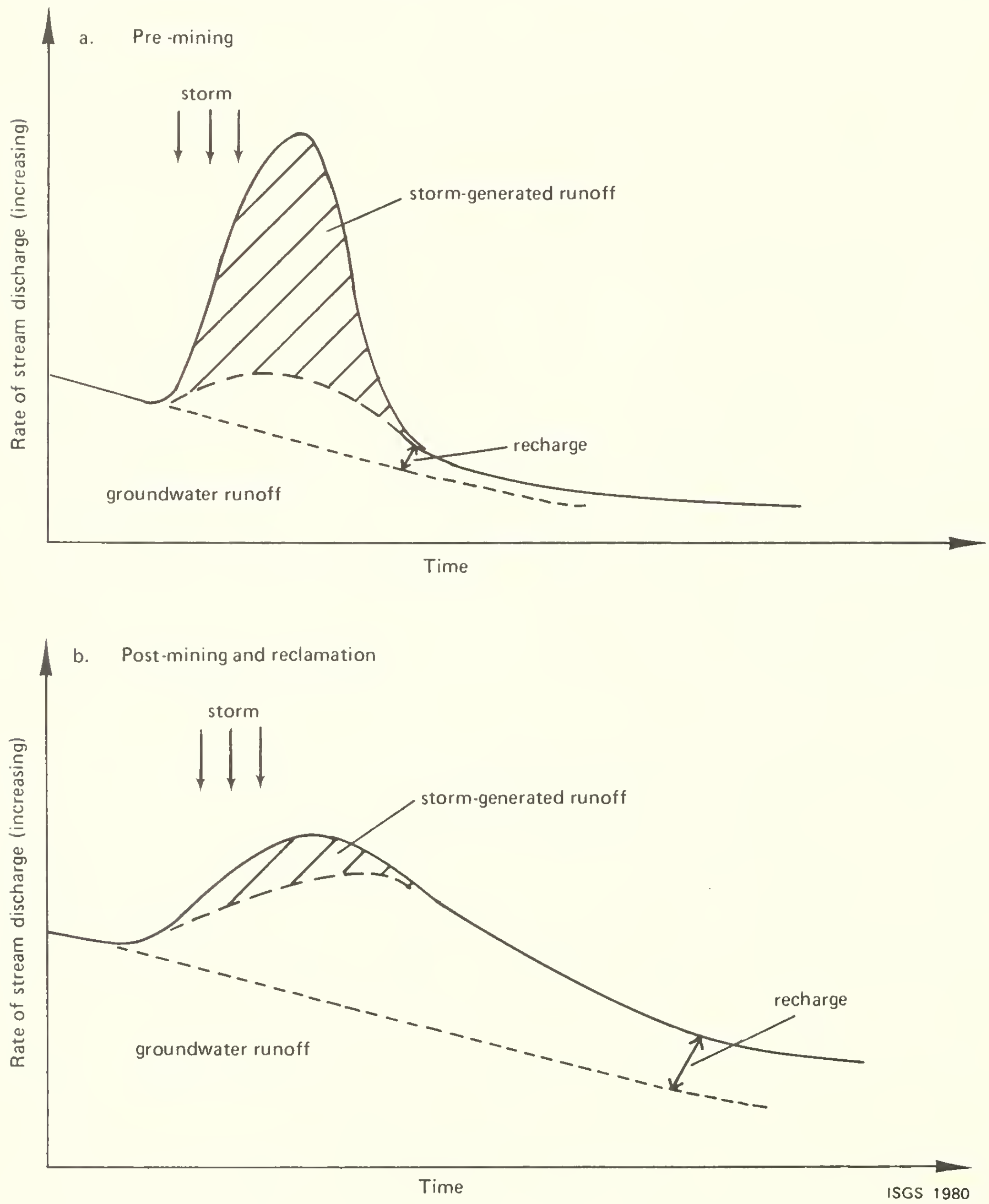


Figure 9. Hypothetical hydrographs illustrating the effect of mining on stream runoff (when mine pits are left to fill with water after mining operations cease).

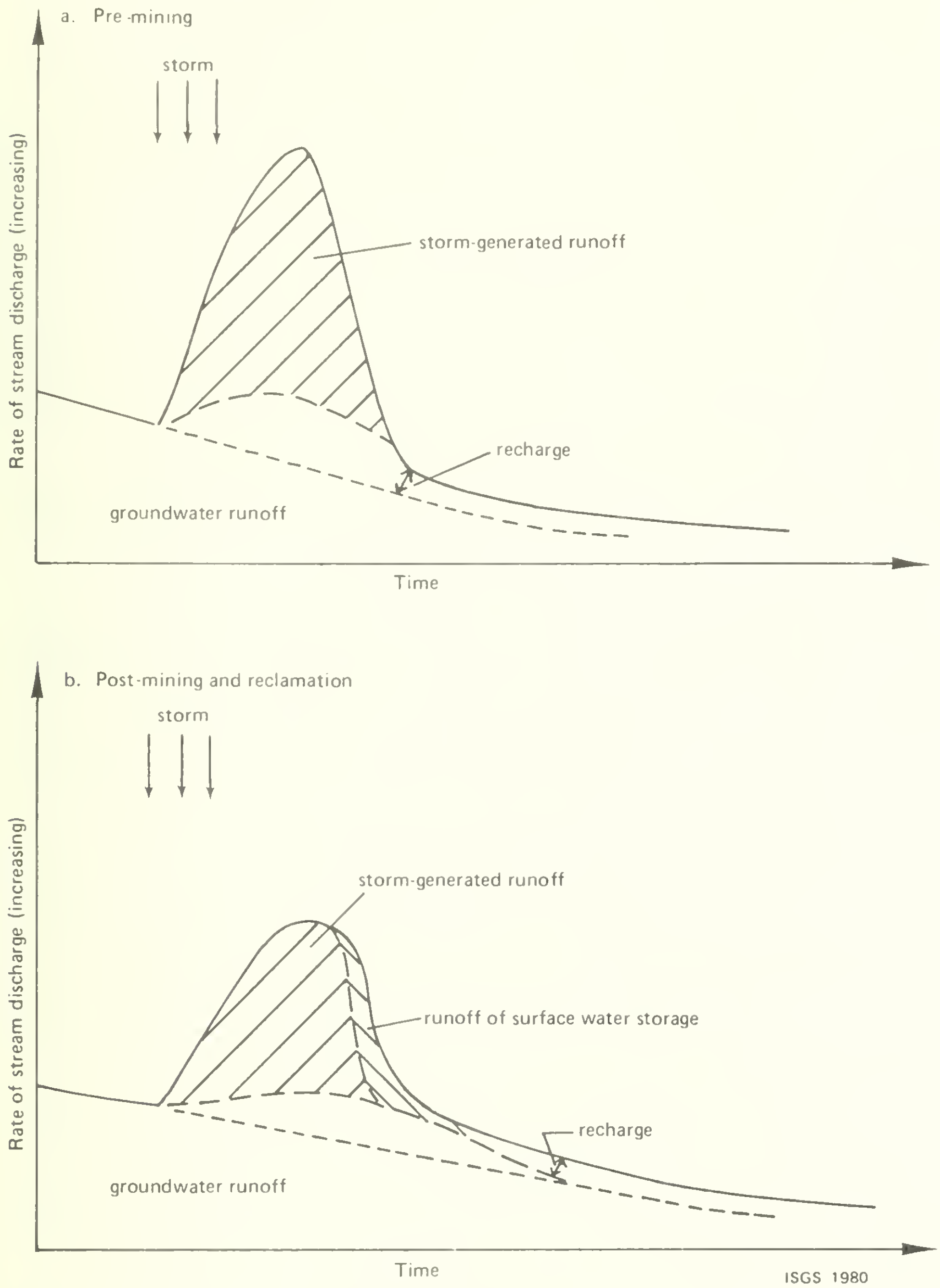
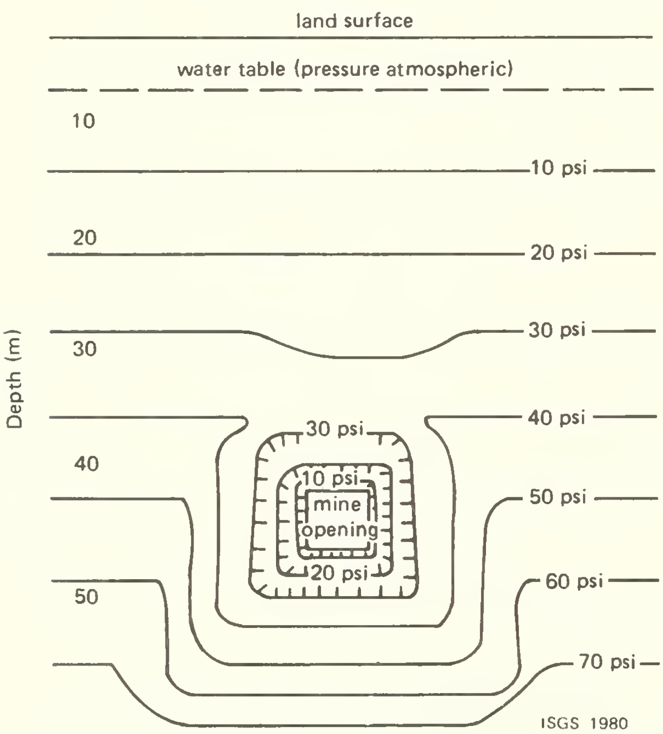


Figure 10. Hypothetical hydrographs illustrating the effect of mining on stream runoff (when a mine is reclaimed with spoil more permeable than the natural geologic materials).

have remained dry for years after mining operations have ceased, and investigators conducting studies in underground mines have noted that the amount of water entering the mines is highly variable from mine to mine and sometimes even within a single mine. Such observations have prompted questions concerning the relationship between the mine and the hydrogeologic environment into which it is placed. It seems obvious that thorough investigation of the hydrogeologic conditions in an underground mine could both improve the

mining operation itself and prevent environmental problems during and after mining—yet only a few studies have been made of hydrogeologic conditions of mines before, during, and after mining. The most notable in the United States are the studies of Pennsylvanian mines conducted by Drown and Parizek (1971) and Lovell and Gunnett (1974), who were interested in water quality of mine discharges. Cartwright and Hunt (1978) used piezometers to monitor water pressures in the roof of an Illinois mine. Most of the data relevant to the hydrogeologic setting of coal mines is buried in literature on mine dewatering techniques, acid mine water problems, mine-related aquifer overpumping problems, and tunneling, and is difficult to find. (For a good example of this problem, see Larsson et al., 1977).

Figure 11 is a diagram of a mine void at a depth of 45 meters (150 ft). The mine void is probably at atmospheric pressure. The pressure lines on the diagram are based on the estimated hydrostatic pressures at that depth. Since the hydrostatic pressure of the water at a particular point is due to the weight of the overlying water, the hydrostatic pressure increases with depth. At the depth of the mine, the hydrostatic pressure would be about 50 pounds per square inch (psi). When the mine void is opened a pressure gradient toward the mine is established and water flows toward the mine because of the differential pressures. The character of the rock significantly affects the way the water responds to these pressures, and also affects the patterns of ground water flow; for instance, in formations with high



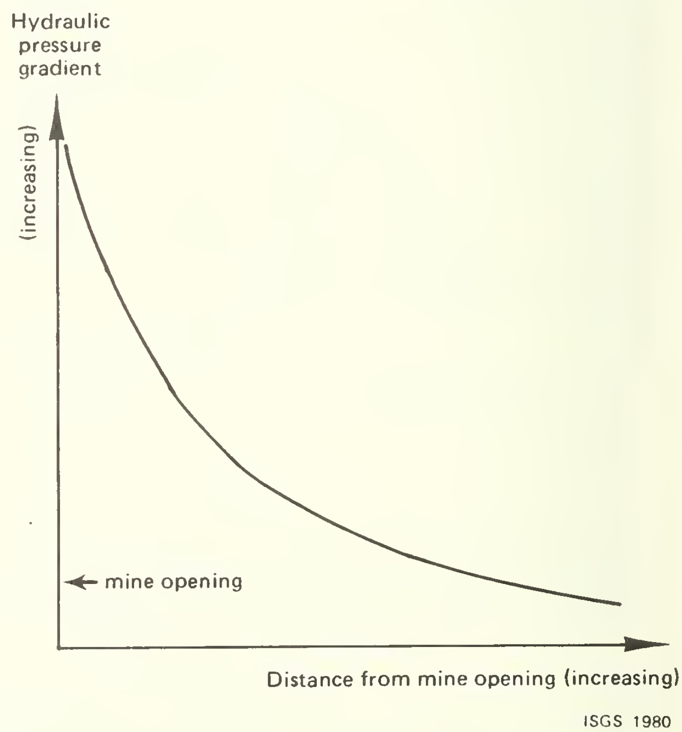


Figure 11. Hydraulic pressure around a mine opening.

Figure 12. Hydraulic gradient in the vicinity of a mine void.

hydraulic conductivities there may be continual flow into the mine over a long period of time; in formations with low hydraulic conductivities the flow may be low and of short duration.

Figure 12 is a simplified diagram showing the hydraulic pressure gradient as a function of distance from the mine at a constant time (Cartwright and Hunt, 1978). The hydraulic gradient near the mine wall is high (in other words, the rate of change of hydraulic pressures in the mine wall close to the mine is high); at some distance from the mine the hydraulic pressure gradient decreases to almost zero. The relative scale of each axis is determined by the depth of the mine and the hydraulic conductivities of the rocks. In rocks with lower hydraulic conductivities (such as those generally associated with Illinois coals) the pressure change will occur over relatively short distances. In areas where sandstone or highly fractured rocks are present, the pressure change may be spread over longer distances.

There are several hydrogeologic settings in which water problems are particularly likely to occur in underground mines. The most common hydrogeologic setting in which large volumes of water may enter a mine occurs when a buried sand-filled channel within the coal-bearing rocks is encountered during mining. These channels occur at several stratigraphic positions and are widely distributed. A number of major channels in the coal basin have been mapped, such as the Walshville Channel, associated with Herrin (No. 6) Coal. As mining approaches the channel sandstone, increasing volumes of water begin to enter through the working face. In many such mines, the coal seam itself is fractured, forming a permeable zone for water movement from the channel sandstone. Thus, as a sandstone channel is approached, increasing volumes of water may flow into the mine through the coal as a result of increasing hydraulic pressure differences between the mine face and the channel sandstone.

Another hydrogeologic situation which may lead to an influx of large volumes of water (particularly in shallow mines) occurs where ancient bedrock valleys have been cut down into or near the coal seam prior to and during the Pleistocene glaciations, leaving a thin mine roof. Pleistocene gravels, frequently found in the base of sediments filling these ancient valleys, are often major aquifers with moderate to high capacities. The depth and location of these valleys are generally well known from drilling records. As mining progresses toward these channels, water and stability problems may become more severe.

A third situation likely to cause water problems in a mine occurs when a thin blanket sandstone acts as a ground water reservoir. These sandstones occur at many stratigraphic positions within the Pennsylvanian. Water flows from this type of sandstone to the mine at very low to moderate rates, depending on the thickness and hydraulic conductivity of the sandstone and intervening roof rocks. In these mines, the volume of water in the sandstone is generally not great enough to cause severe mining problems but does become a nuisance, particularly where the mine floor is a thick, soft, swelling clay.

The hydrogeologic setting of the coal in the Illinois Basin Coal Field is normally not affected by major tectonic deformation, so the influence of major folds, faults, joints and fracture traces on the hydrogeology of the

mines is minimal or absent. However, recent work in the Illinois coal mines (Krausse et al., 1978) has shown that many small-scale structural features (slips, faults, joints) occur in the coal and the strata above it. These small structures in a mining area may also indicate minor changes in the ground water flow pattern and the volume of ground water flow. The permeability of fractured rocks is greater than that of the same rocks in an unfractured state; thus, increased flow may often be found in the vicinity of these structures.

Progressive drainage and rewetting during mining may weaken the mine roof and floor materials, and repeated wetting and drying could further weaken the rocks. For example, in the city of Streator, Illinois, sewage has been dumped into the old mine workings for many years and allowed to move laterally through the workings, discharging to the Vermilion River. Current studies undertaken to control the sewage discharge suggest that repeated wetting and drying will significantly reduce the strength of the rocks and therefore increase the incidences of mine subsidence. Thus, any change in the hydrogeologic regime of a mine, such as backfilling a dry mine with water (man-induced or natural) or pumping water from a mine which has filled, may weaken the rocks and precipitate increased rates of subsidence and surface damage. Severe inundation does not occur in most deep coal mines in Illinois, and the depletion and drainage of aquifers in mine dewatering operations is generally not a problem. In areas of Illinois in which the Pennsylvanian series is the uppermost bedrock unit, the ground water becomes mineralized at an average depth of less than 100 meters (about 300 ft). Most Illinois coal mines are in bedrock which contains mineralized water, and wells for water supplies are finished at shallower depths in aquifers with potable ground water. Contamination of water wells from mine dewatering systems and holding ponds is rare in Illinois; however, as mines are opened at greater depths in rocks containing more highly mineralized water, it is possible that disposal of the water entering the mine will have to be handled differently to protect streams and shallow aquifers.

SUMMARY

Detailed analysis of the hydrogeology of mining areas before, during, and after mining can help prevent problems that may occur in and around the mines. Such study should include:

1. A study of the topography of the land surface and the patterns of surface flow. (This is especially important for surface mines, which often disturb surface flow in some way.) If necessary, streams can be diverted during mining and reestablished during reclamation. An accurate description of the surface relief of the area made prior to mining can also facilitate reclamation. An understanding of surface flow and topography is necessary to ensure that holding ponds, gob piles and coal piles are placed properly to prevent contamination of streams or shallow aquifers.

2. The identification and characterization of aquifers in the glacial drift and in the bedrock, especially their thickness, lateral extent and hydrogeologic properties (hydraulic conductivity and water quality). The effects of any faulting in the area on the hydraulic conductivity of the aquifer should be studied, and data on well yields and water quality should be obtained through a survey of area water wells and test borings. Such

information will help determine whether an aquifer yields potable water; whether it is of local or regional extent; whether it is utilized primarily for small and/or large ground water supplies; and whether it is the only or the dominant aquifer in an area.

3. A prediction of the effects of mining on surface streams and aquifers. In Illinois, potential concerns include: (a) contamination of streams or drift aquifers by mineralized water drained from surface or underground mines or by water draining off spoil piles and entering flow systems; (b) the distance from the highwall of a surface mine that a shallow aquifer may be drained during mining; and (c) the presence of a bedrock aquifer which may affect or be affected by an underground mine.

4. An assessment of the effects of surface or groundwater flow on mining. Ground water has been implicated in some roof-fall and floor-heave cases. Serious inundation of mines is not a problem in Illinois, and there are no major regional aquifers in the Pennsylvanian Series in the Illinois Basin; however, a careful study of the hydrogeologic conditions in the mine is useful in designing the most economical dewatering system.

With information gained in such studies, mines can be designed to be productive, efficient, and environmentally sound.

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